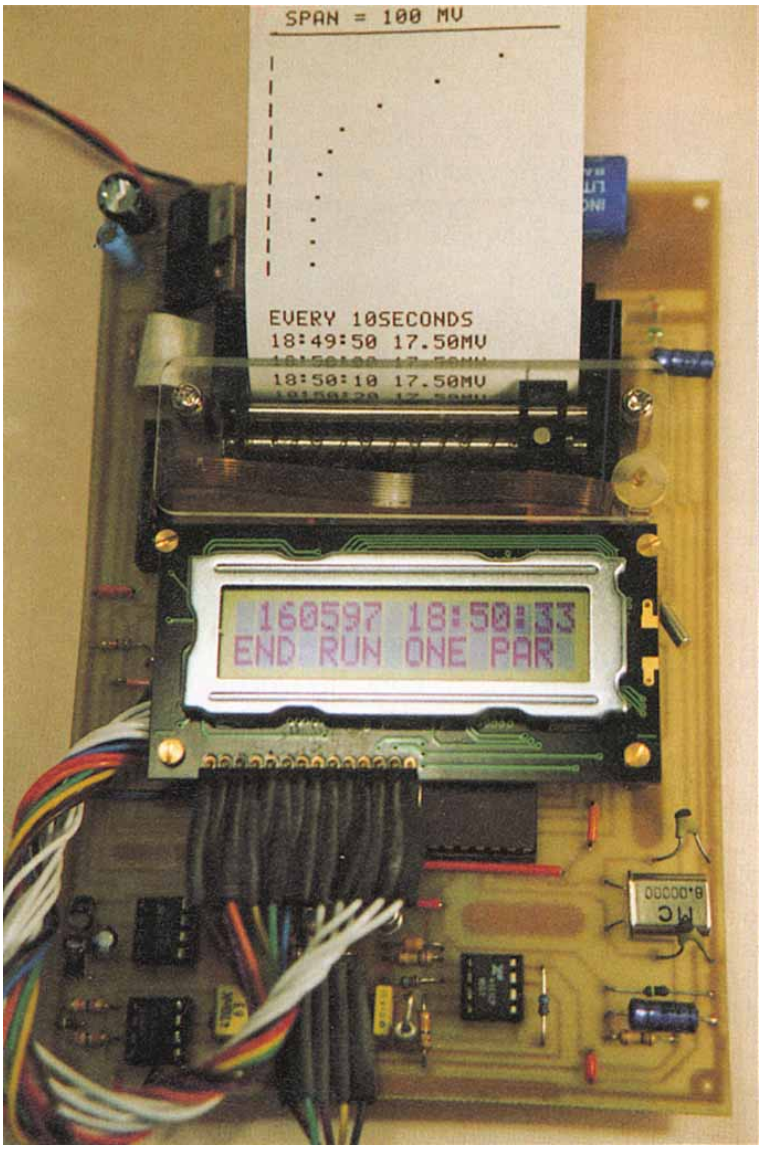
A Thermal Printing Voltmeter

*by Kevin F Scott MA(Cantab) D Phil(Oxon), MM0BPX**

THERE ARE MANY advantages in obtaining a printed record of DC voltage measurements when experimenting or monitoring slowly varying signals. It might be required to monitor the discharge of rechargeable cells, or the temperature of an oven or furnace, or the output of any sensor measuring slowly changing physical quantities. Obtaining a printed record of voltages with time or a plot of the signal along a time axis is often an essential requirement in many investigations. Until recently, the usual way of doing this was to use a recording ammeter or voltmeter or a potentiometric recorder in which the position of a pen was controlled by a motor which automatically balanced a bridge circuit by rotating a potentiometer. The main alternative to this is provided by an analogue-to-digital converter coupled to a computer, and there are several excellent commercial versions of this available.



The completed project, showing the plot of a gradually decaying voltage.

However, both the potentiometric recorder and the a/d converter/computer options are relatively expensive and rather bulky. Ideally, the main recording functions should be available in an instrument not much larger than a digital multimeter, and available also at a budget price. This article describes the use of small thermal print heads of the type used to produce bar-code labels to realise simple recording devices for monitoring slowly changing signals. The principles are applied to the realisation of a recording millivoltmeter and plotter for which circuit details and constructional information is given and for which software is being made available.

*Kirklands, Craigend Road, Stow, Galashiels, Scotland TD1 2RJ.

THERMAL PRINT HEAD

THE THERMAL PRINT head used in this work was the MTP201-20B, available from Amega Electronics [1]. The motor, when activated by a 5-6 Volt supply, rotates the carriage drive shaft at the front of the printer, which has a double helical groove machined into it. When it rotates, the print head moves along the carriage and then returns. When it does so, a vaned shaft behind it engages by friction with the thermal paper passing under it and causes the paper to feed upwards by a fixed amount. At the same time, a microswitch closes at left hand side of the carriage which enables the controlling microprocessor to detect that the print head has reached the left-most position. The motor also has a tacho output, which generates 240 pulses during the time taken for the print head to move fully across the paper. This tacho output can be used to synchronise the pulses sent to the print head, to enable reliable character generation.

The print head itself consists of 7 tiny heaters, arranged in a vertical line. Each heater has a resistance of about 14Ω and when supplied by a 5-6V supply they get sufficiently hot to blacken the thermal paper. Current must only be applied momentarily to these heaters, or they will burn out. About 1-2 seconds is the maximum. Under normal circumstances, currents are driven through the heaters for much smaller intervals than this (typically 10ms). The 7 elements of the print head are conveniently driven from a microcontroller 8 bit parallel port via a source driver IC. The unused bit of the port can conveniently be used to control the motor. There is also a need for two input lines in the microcontroller, for the tacho signal from the motor and the carriage return signal from the microswitch. In this design, a further output line from the microcontroller was used to control the current supply to the source driver via a logic

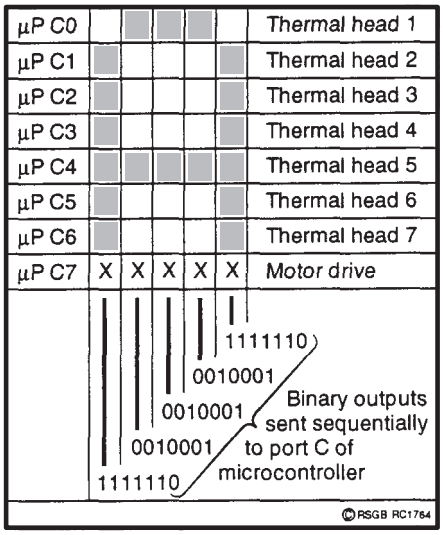


Fig 1: Construction of the letter A on a 7-head thermal printer.

MOSFET. This was needed as the 8 bit port used to control the thermal head of the printer was also used to supply characters to a Hitachi alphanumeric LCD display. When the latter was being addressed, it was necessary to disable the thermal print head.

COMPONENTS

Resistors: all 0.25W carbon film 5% tolerance unless otherwise stated.

R1, R10, R13, R14, R15, R16, R18, R19, and R20	10k
R2, R5, R11	100k
R3	6k8 1%
R4	14k
R6, R7	1k0 1%
R8, R12	1M0
R9	39k 1%
R17	18k
R21	100R
RV1	10k multi-turn trimpot

Capacitors

C1	470µF 16V Electrolytic
C2	10nF Polyester
C3	1nF Polyester
C4	100nF Polyester
C5	470nF Polyester
C6, C7, C18	33µF 10V Electrolytic
C8	150µF 10V Electrolytic
C9	220µF 10V Electrolytic
C10, C11, C17	10µF 10V Electrolytic
C12	100µF 10V Electrolytic
C13, C15, C16	15pF Ceramic
C14	30pF Trimmer

Semiconductors

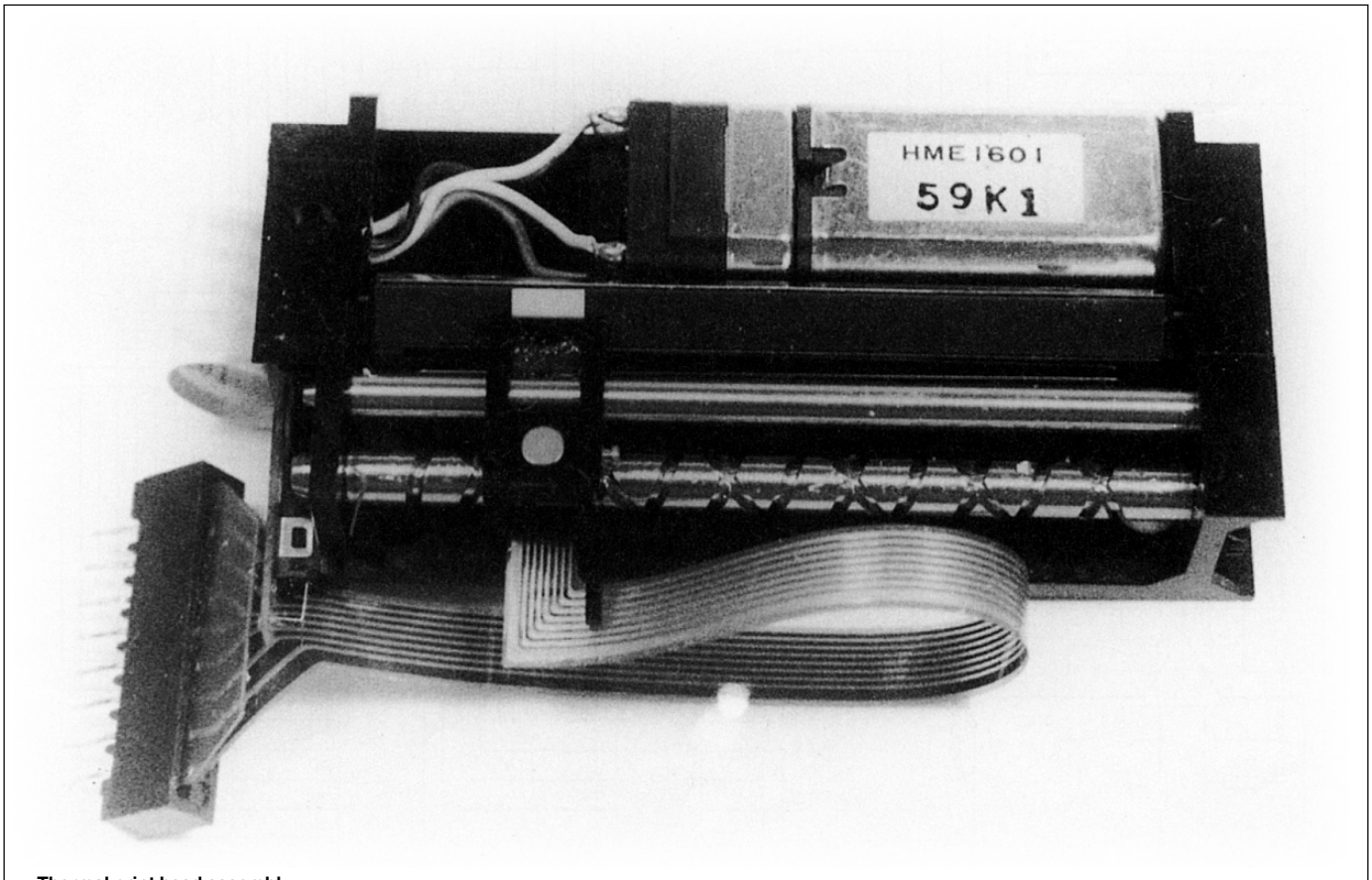
D1	1N4001
D2, D3	OA91 or OA47
TR1	BUZ10L
TR2	BC109
REG1	78L05
REG2	78L08
REG3	7805
REG4	SI7660CJ
IC1	CA3140
IC2	RC4152
IC3	TMS77C82NL pre-programmed*
IC4	MSM6242BRS
IC5	UDN2981A

Miscellaneous

X1	8.000MHz
X2	32.768kHz
DSP1	Hitachi LM061 display module
B1	3.7V lithium battery
H1	14 way right angle PCB header, 0.1in pitch
H2	5 way right angle PCB header, 0.1in pitch
PT1	MTP201 -20B thermal printer

CHARACTER GENERATION AND POINT PLOTTING

THE PRINTER as supplied can only be enabled to print characters if the thermal printhead is supplied with the appropriate sequence of pulses, synchronised with the tacho pulse. **Fig 1** show the structure of a letter 'A' as an example of the manner in which characters are constructed. The configuration used is the same as that in the 5x7 matrix of a Hitachi LCD display. The same patterns provide a convenient format for printed characters also.



Thermal print head assembly.

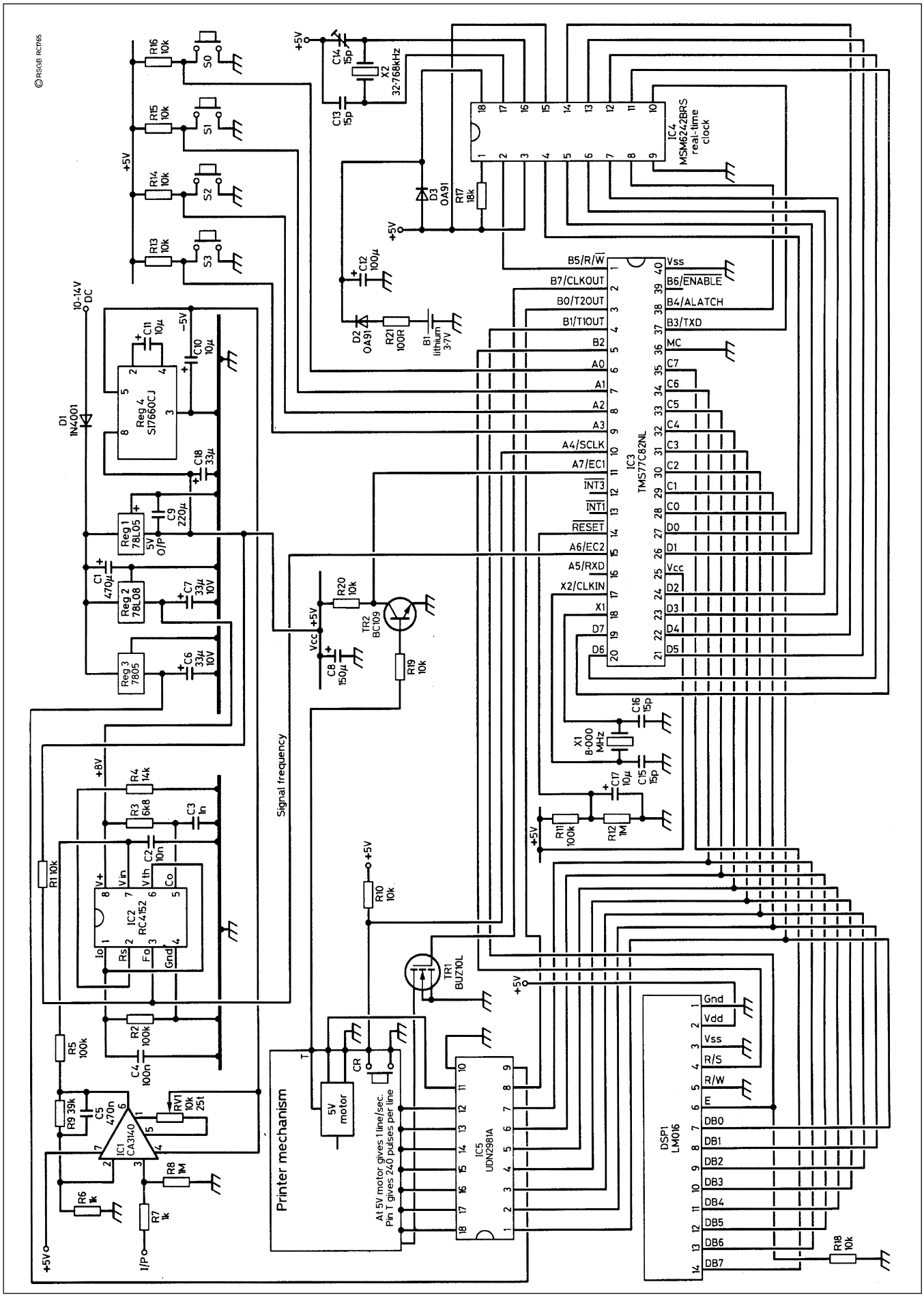


Fig 2: Circuit diagram of the thermal printing voltmeter.

To construct a character generator in software, each 7-bit column can be stored in an appropriate memory location at the time the microcontroller is programmed. So, to form any required character, the contents of 5 such locations must be read and supplied sequentially to the thermal print-head, the duration of each being controlled by the tacho pulse from the motor.

Using the printer as a plotter is very simple. To plot a point at a certain distance from the left hand homing position, the print head is driven from left to right while counting the tacho-pulses.

When the number counted corresponds to the scaled voltage to be plotted, one or more print head heaters are activated for a further one or two tacho counts. The result is that a point is plotted on the paper at the appropriate place.

PRACTICAL DESIGN

THE CIRCUIT FOR a printing and plotting millivoltmeter using the MTP201-20B printer and Texas Instruments TMS77C82NL microcontroller is shown in **Fig 2**. The TMS77C82NL was chosen for its 8k on-board ROM and its four 8 bit ports, giving a total of 32 lines, almost all of which are required to realise a versatile instrument. The programmed microcontroller is given instructions by means of four press buttons, S0 - S3, which perform several different functions each. The microcontroller has four other peripheral devices or circuits: A Hitachi LM016 LCD display, a MSM6242BRS clock, the MPT printer head and its associated drive circuitry, and a single channel A/D convertor which utilises an RC4152 voltage to frequency convertor.

MAJOR COMPONENTS

THE LCD DISPLAY

The Hitachi LM016 is a two line display utilising the now almost universal driver IC, the HD44780. It is operated in 8 bit mode and connected to the C port of the microcontroller, which it shares with the printer. Two control lines, E and R/S, are connected to port lines B1 and B2, and are used to set the operating mode of the display and to enable characters sent on the C port lines to be written to the display. At switch on, the display shows the date and time on the top line and a menu which corresponds to the four control buttons S0-S3. These allow the user to select either parameter adjustment, (clock setting, or timebase control) or one of functions of the device: display, print or plot. Selection of one of these options generates further menus.

THE PRINTER

The mode of operation of the printer has already been described. The print heads are controlled via IC5, which is a UDN2981A source driver, and the printhead current inhibited when a zero is written to line B7 by the software. The tacho signal from the motor is fed to Q3 which gives a logic level signal at A7. The carriage return microwitch grounds A4 when the print-head is in the left hand position.

THE CLOCK

The clock is an MSM6242BRS, with four data lines and four address lines, crystal control, fine timekeeping adjustment via trimmer C14, and a Lithium battery backup. The clock registers can be edited when the parameter adjustment menu is selected and contains year, month, date, hour, minute and second information. The clock has auto leap year facility.

A/D CONVERTER

The input signal is amplified by IC1 with a gain of 40, and the output fed to the RC4152 Voltage to frequency converter. This has very good stability and linearity, and was chosen because it requires only a single input line into the microcontroller and functioned well under test. The conversion factor depends on C3 and R3, which are both 1% tolerance components or better. The

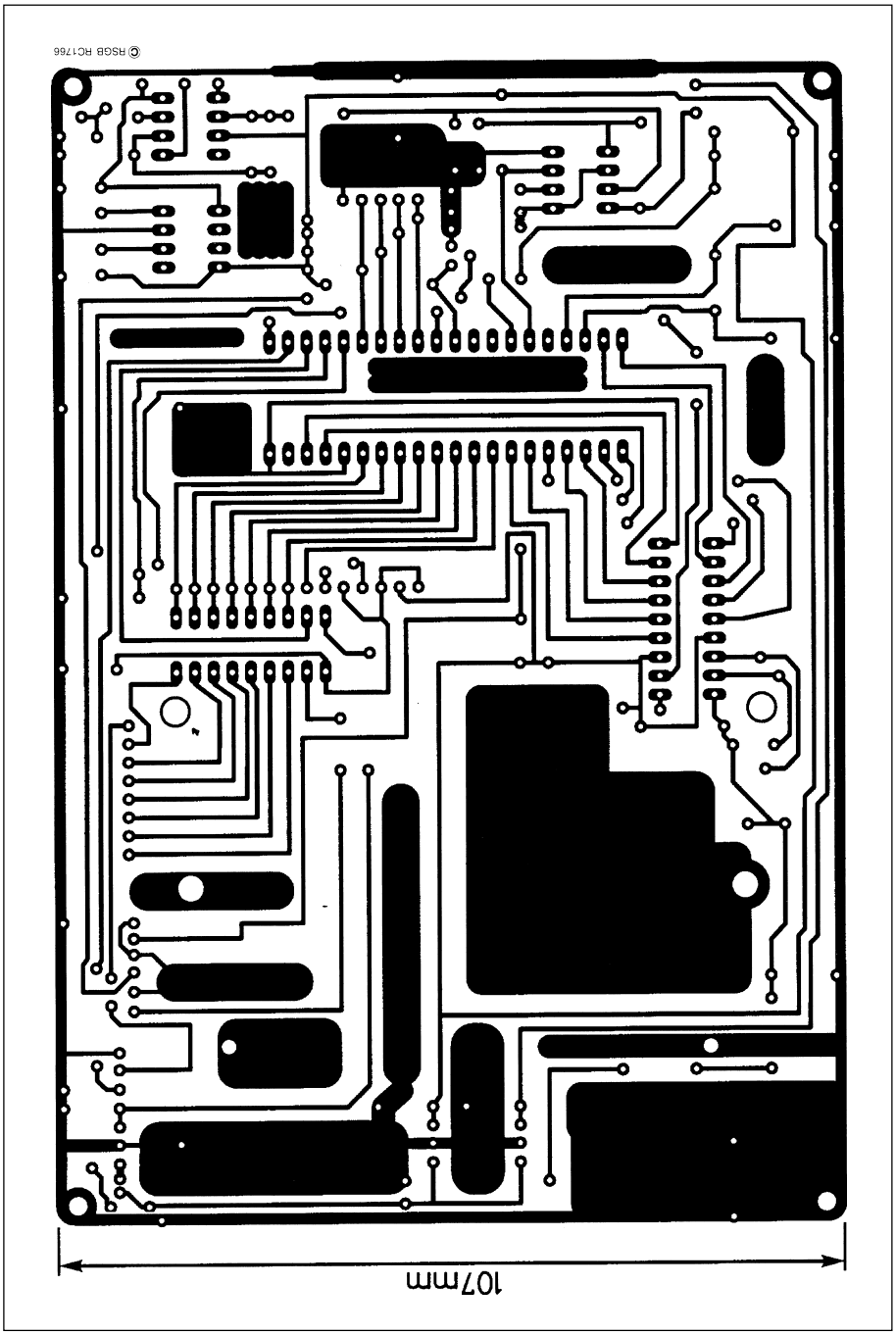


Fig 3: Track layout of the single sided PCB.

calibration of the instrument can be adjusted in two other ways, by making adjustments to the software or by adjustment of the gain-controlling components on IC1 (R6 and R9).

On the software side, the converter works by providing a timed software gate during which period the pulses from the converter are counted into a 16 bit register in BCD format. This gives a count of 0000 to 9999, and with the component values of Fig 1, the gate was arranged to give a range of 0 to 99.99mV. Positive voltages only are converted, negative voltages cannot be measured, a disadvantage partially mitigated by the zero adjustment control on IC1 which can be used to offset the input if the signal falls outside the range on either side.

PRINTED CIRCUIT BOARD

THE TRACK SIDE and the component overlay of the printed circuit board are shown in **Fig 3** and **Fig 4** respectively. The board is single-sided, which means that a number of links are needed on the component side, but this disadvantage is offset by the absence of the requirement of accurate registration of two printed sides. After populating the board, the LCD display can be installed on stand-offs such that its upper surface is level with the top of the printer module. It can then be installed onto a front panel provided with appropriate cut-outs. In the prototype, a simple stand was also fashioned out of steel rod to support the roll of thermal paper.

Diodes D2 and D3 are Germanium types and are vulnerable to excessive heat on soldering. IC3 and IC4 are static sensitive, as is TR1.

SET-UP AND OPERATION

AT SWITCH ON, the motor on the printer will run for about a second and the thermal print head will be activated, making a solid black line on the paper. This confirms that it is functioning correctly. After a further second, the screen will show the date and time and the main menu. Pressing PAR (Parameters) and selecting CLK will enable the clock to be set to the correct date and time. Pressing END will return to the parameter menu, from which TMB (Timebase) can be selected. The frequency of measurement, from continuous operation (once every 2 seconds) to once per hour can be selected in 9 steps. Pressing END successively will return to the main menu, and print the selected timebase as a reminder to the user of the setting selected. The user then can select DSP (Display), PRN (Print), or PLT (Plot). If DSP or PRN are selected, a further menu allows single readings to be taken whenever the operator requires by pressing a button, or sequential readings may be chosen and these will be taken at the rate selected by the user under the TMB menu. If PLT is selected, the choice is of a span of 10mV or 100mV, and the printer will print the chosen span, the axes and the data points as they are recorded.

The device should find many uses in the electronics workshop.

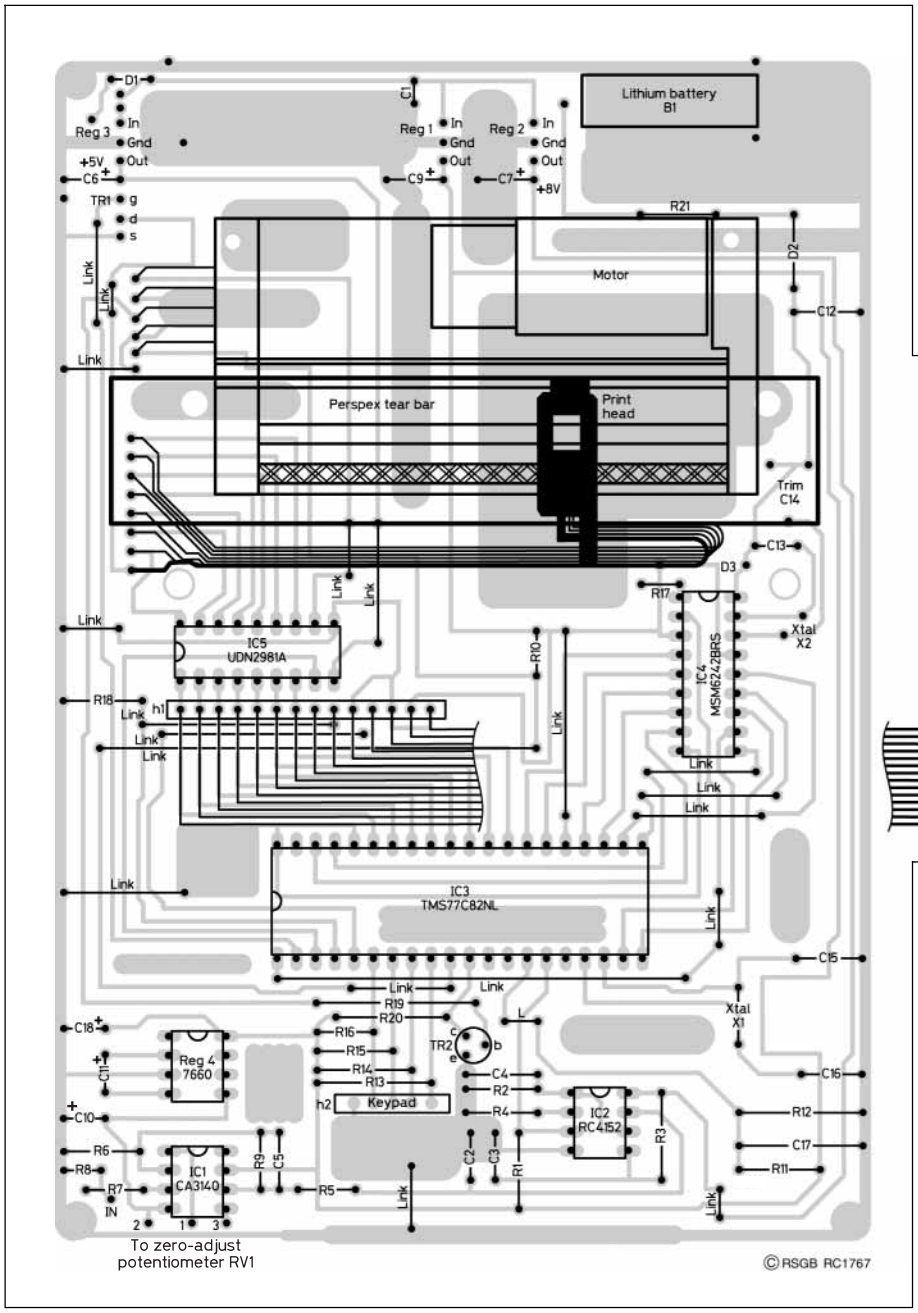
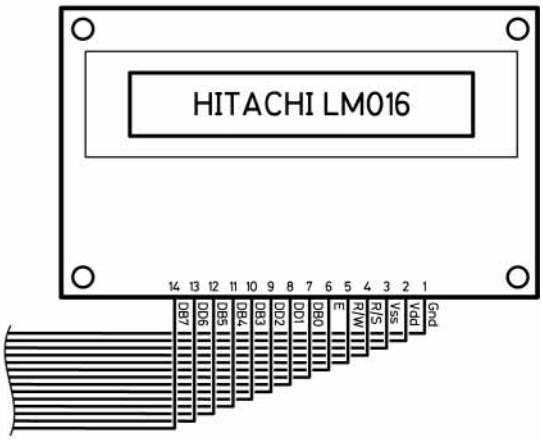


Fig 4: Component overlay details of the PCB.



REFERENCE

[1] Amega Electronics, Loddon Business Centre, Roentgen Road, Daneshill East, Basingstoke, Hampshire RG24 8NG. ♦

● *A set of parts including pre-programmed microcontroller and a PCB are being prepared for this project by JAB Electronics, PO Box 5774, Birmingham B44 8PJ.*